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THE LIFE-HISTORY OF *PSYLLA ISITIS* BUCKT. (*PSYLLOPA PUNCTIPENNIS*, CRAWFORD) THE "PSYLLA" DISEASE OF INDIGO

BY

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AND

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Assistant to the Imperial Entomologist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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PLATE XV.

INDIGO PSYLLA.

EXPLANATION OF PLATE XV.

1. Eggs laid in the groove of a leaf-stalk. X 16.
2. Egg a few hours old. X 64.
3. Egg about a day old. X 64.
4. Nymph, first stage. X 64.
5. " second " X 50.
6. " third " X 45.
7. " fourth " X 30.
8. " fifth " X 20.
9. Imago, female. X 20.
10. The hind end of the abdomen of male. X 20.
11. An adult female sitting on a shoot. X 2.
12. The head of a Java-Natal indigo plant showing crumpling of the leaves produced by the feeding of the nymphs; with a nymph sitting just below the head.

EXPLANATION OF PLATE XV.

1. Eggs laid in the groove of a leaf-stalk. X 16.
2. Egg a few hours old. X 64.
3. Egg about a day old. X 64.
4. Nymph, first stage. X 64.
5. " second " X 30.
6. " third " X 15.
7. " fourth " X 20.
8. " fifth " X 20.
9. Imago, female. X 20.
10. The hind end of the abdomen of male. X 20.
11. An adult female sitting on a stool. X 2.
12. The head of a Java-Natal indigo plant showing crumpling of the leaves produced by the feeding of the nymphs; with a nymph sitting just below the head.

PREFACE.

The observations included in this Memoir were made in connection with the investigation into the pests of Indigo in Behar which was taken up at the request of the Behar Planters' Association in December 1911. A general account of the pest and its relation to other diseases of Indigo was published by Mr. H. Maxwell-Lefroy, the former Imperial Entomologist, in the Agricultural Journal of India, Vol. VIII, Part 1, and the details of more scientific interest are included in this Memoir. This number will complete Vol. IV.

PUSA,
November 21st, 1913.

A. J. GROVE,
Offg. Imperial Entomologist.

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INTRODUCTION.

The pest of the indigo plant which has become known in Behar as Indigo "Psylla" is accountable for a great deal of damage to the indigo crop, though as has been stated by Lefroy (Agric. Journ. India, Vol. VIII, pt. 1), it cannot be held entirely responsible for the failure, especially of the *khoontie* crop, in recent years.

A Psyllid attacking indigo was first described by Buckton (Indian Museum Notes, Vol. II, page 18), but in the account given by Cotes it is stated: "The indigo shoots were found covered with minute black scales each containing a partially developed Homopterous insect, which was at first supposed to be one of the Aphidæ, but which has since been described by Mr. G. B. Buckton as a pupa of a new species of Psyllidæ, which he names *Psylla isitis*." These black scales were probably an Aleyrodid which is common on indigo and had no connection with the Psyllid. On page 167 of the same volume of Indian Museum Notes, *Psylla isitis* is put down as "a minute insect, which forms galls on indigo (*Indigofera tinctoria*) plants. It was reported in 1896 as excessively destructive to indigo in Bengal." Here, again, the hard knot of curled leaves produced by the attack of the insects has probably been

mistaken for a gall. Buckton's description of the specimens sent to him is as follows:—

Psylla isitis, nov. sp.

"*Pupa.*—Colour shining yellow with the edges of the abdominal somatic rings rich brown. Vertex bristly, eyes angularly facetted, large and red. Rostrum short and stout, proceeding from between the eyes, and lying between the fore coxæ. Pronotum corrugated and tuberculose. Antenna with eight joints, the two basal joints stout and somewhat globose; the third and eighth joints the longest. Wing-cases double, but not separate. Abdomen globose, the somata edged with rich brown, and marked with stigmata. Tarsus obscurely two-jointed, ending with one claw and two bristles. The larval form is smaller than the pupal, and has less developed antennæ and feet. Size 0·05 × 0·03 of inch."

This does not give a very accurate description when compared with living specimens, and the figure given is not good.

Crawford has recently described the insect from adult specimens sent from the Pusa collection and has called it *Psyllopa punctipennis* and in his description (see page 340) says that this is probably the same as Buckton's *Psylla isitis*. but in order to avoid confusion, has given it a new name.

An examination of Buckton's type specimens leaves little doubt that the insects described by Buckton and Crawford are identical so that both names have been given.

The name "Psylla" has arisen from the name given to the insect by Buckton and has become so firmly established as a common name for the insect that it has been retained and is used as such in this Memoir.

Life-history.

The insect will breed all the year round provided that suitable food-plants are available. The time which elapses between the laying of the egg and the appearance of the adult however varies at different times in the year according to temperature

conditions. During the cold weather the period may extend to forty-six days (February and March 1913), whilst in the hot weather may be as short as fourteen days (August 1912). As would be expected therefore its attacks are most felt in the *khoontie* crop. This short period necessary for complete development, combined with the large number of eggs which each female is capable of laying explains how the crops in the field become badly attacked in a comparatively short time, especially as only a few nymphs are necessary to produce a marked effect on the plant.

The differences in the length of the period of development are shown in the following table:—

Date of oviposition.	Date of hatching.	Date of emergence of adult.	Period.
February 25th, 1912 ..	March 6th ..	March 25th ..	30 days.
March 1st	March 11th ..	March 30th ..	30 ,,
April 15th	April 24th ..	May 6th ..	22 ,,
May 10th	May 18th ..	June 1st ..	23 ,,
June 20th	June 24th ..	July 6th ..	17 ,,
July 7th	July 11th ..	July 24th ..	18 ,,
August 21st	August 25th ..	September 8th ..	19 ,,
September 8th ..	September 11th ..	September 30th ..	23 ,,
January 26th, 1913 ..	February 15th ..	March 12th ..	46 ,,
February 1st ,, ..	February 22nd ..	March 16th ..	44 ,,

The number of broods is probably from twelve to fourteen. Nine generations were traced between February and September 1912, when it was found impracticable to carry the experiment further. The generations are as follows:—

Generation.	Date of oviposition.	Date of emergence of adult.	Period.
First ..	25th-27th February 1912 ..	26th March 1912 ..	29 days.
Second ..	28th March	24th April	28 ,,
Third ..	25th April	20th May	26 ,,
Fourth ..	24th May	16th June	23 ,,
Fifth ..	21st June	8th July	20 ,,
Sixth ..	11th July	28th July	18 ,,
Seventh ..	3rd August	21st August ..	19 ,,
Eighth ..	25th (?) August ..	7th September ..	14(?) ,,
Ninth ..	10th September ..	27th September ..	18 ,,

The egg.—The egg (Plate XV, figs. 1-3) is small, spindle-shaped when seen from above, tapering to each end, one end being broader than the other. It measures ·25 m.m. in length and ·1 m.m. in thickness at about the middle. The surface of the egg-shell

is smooth. When freshly laid it is palish yellow in colour with a tinge of orange at the broader end. After a few hours it gradually darkens in colour becoming eventually quite black. This only applies to fertile eggs. Unfertilised ones become a little darker after they are laid but never become quite black and of course never hatch. The eggs are fastened to the surface on which they are laid by a curious projection of the egg-shell. About one-third of the length of the egg from the broader end the egg-shell is pulled out into a rounded protuberance which is buried in the tissues of the plant and holds the egg in position on the plant. The situation chosen by the female for oviposition is not constant, but the greatest number of eggs was observed in the groove of the rachis of the leaves. Almost any site on the plant may be chosen and eggs have been found on the stem, in the axils of the leaflets and of leaves and on the upper and lower surfaces of the leaflets. The positions are, however, always selected with a view to affording protection to the egg, for even when laid upon the stem the eggs are almost invariably placed in the grooves on the surface and when deposited on the leaves they are mostly found in the furrow of the midrib or smaller veins or by the side of raised veins.

The eggs are laid singly, the protuberance of each being thrust into the tissues of the plant separately. No definite order was observed, but the eggs are generally laid in rows at varying distances apart in a groove or furrow on the plant with their long axes pointing in the direction of the furrow, but because of the nature of their attachment to the plant never one on top of another. On the surface of the leaf or under the stipules a few are often placed side by side with their long axes parallel.

Varying numbers of eggs laid by different females have been observed, the numbers ranging from 208 to 828. The following tables give the record of the oviposition of several females:—

Two females A and B emerged on February 20th and were kept together in a cage along with several males. Between 21st and 22nd, 34 eggs were laid and the females were taken out and confined alone on separate plants. The oviposition records of

each are shown separately. Both escaped alive, A on March 15th and B on March 7th. The eggs laid by A between 11th and 15th March were not all fertile as some of them did not hatch. With B too, of the eggs laid between 3rd and 7th March, only one hatched and the rest were unfertile and failed to hatch.

OVIPOSITION RECORD OF A.

Period.	On stem.	On stem at axils of leafstalks or by the side of stipules or buds.	In groove of rachis of leaf.	At axils of leaflets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
10 A.M. 22 Feb. to 10 A.M. 23 Feb.	1	..	4	1	1	3	10
10 A.M. 23 ,, to 4 P.M. 24 ,,	4	5	6	..	1	6	22
4 P.M. 24 ,, to 9 A.M. 25 ,,	2	1	..	..	1	3	7
9 A.M. 25 ,, to 2 P.M. 27 ,,	7	23	34	..	..	7	71
2 P.M. 27 ,, to 11 A.M. 28 ,,	1	2	6	4	..	..	13
11 A.M. 28 ,, to 10 A.M. 29 ,,	..	9	2	..	..	5	16
10 A.M. 29 ,, to 4 P.M. 1 Mar.	..	10	13	12	7	13	55
4 P.M. 1 Mar. to 11 A.M. 2 ,,	..	..	2	2	..	3	7
11 A.M. 2 ,, to 11 A.M. 3 ,,	3	24	17	6	3	5	58
11 A.M. 3 ,, to 9 A.M. 4 ,,	..	4	3	3	1	..	11
9 A.M. 4 ,, to 10 A.M. 5 ,,	3	8	10	5	2	3	31
10 A.M. 5 ,, to 4 P.M. 7 ,,	..	24	17	11	2	6	60
4 P.M. 7 ,, to 2 P.M. 11 ,,	..	48	55	40	..	16	159
2 P.M. 11 ,, to 8 A.M. 15 ,,	2	5	9	..	..	2	18
							538

OVIPOSITION RECORD OF B.

Period.	On stem.	On stem at axils of leafstalks or by the side of stipules or buds.	In groove of rachis of leaf.	At axils of leaflets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
10 A.M. 23 Feb. to 9 A.M. 25 Feb.	2	8	16	..	1	2	29
9 A.M. 25 ,, to 3 P.M. 27 ,,	8	22	25	11	..	17	83
3 P.M. 27 ,, to 4 P.M. 1 Mar.	16	7	16	16	1	11	67
4 P.M. 1 Mar. to 11 A.M. 3 ,,	..	1	7	7	1	2	18
11 A.M. 3 ,, to 4 P.M. 7 ,,	..	2	9	..	..	..	11
							208

Female C emerged on March 11th, was provided with a male of the same date, was found coupling on March 12th at 9 A.M., and remained in copulation till 10-35 A.M. Eggs were found laid the next morning. 274 eggs were laid in all and all were fertile

and hatched. On March 24th the female was found dead, stuck to the earth in the pot. The oviposition record is as follows :—

FEMALE C.

PERIOD.		On stem.	On stem at axils of leaves or by side of stipules and buds.	In groove of rachi. of leaf.	At axils of leaf-lets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
From	To							
10-35 A.M. 12 Mar.	9 A.M. 15 Mar.	..	1	5	1	4	5	16
9 A.M. 15 ,,	8 A.M. 18 ,,	..	9	40	3	1	9	62
8 A.M. 18 ,,	3 P.M. 21 ,,	4	39	67	13	3	27	153
3 P.M. 21 ,,	23 ,,	3	11	11	9	..	9	43
								274

Female D emerged on the morning of March 30th and was provided with a male which had emerged the day before. The male escaped on April 7th and the female was given another male of this date. The second male too escaped on the 14th and was replaced by a third male. On the 16th April the insects were found coupling at 4 P.M. and ceased to couple at 4-50 P.M. The female died, apparently a natural death, on April 22nd. All the eggs were fertile and hatched. The oviposition record is as follows :—

FEMALE D.

PERIOD.		On stem.	On stem at axils of leaf-stalks or by side of lateral buds or stipules.	In groove of rachis of leaf.	At axils of leaf-lets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
From	To							
30 Mar.	10 A.M. 7 April.	5	36	63	21	7	29	161
10 A.M. 7 April.	10 A.M. 14 ,,	6	91	128	25	3	37	290
10 A.M. 14 ,,	10 A.M. 16 ,,	47	10	21	4	3	..	85
10 A.M. 16 ,,	9 A.M. 21 ,,	1	119	54	..	..	..	174
9 A.M.	....	..	..	..	..	..	..	710

Female E emerged on the morning of March 30th and was provided with a male of the same date. Coupling was observed at 2-45 P.M. and continued till 4-20 P.M. on the 1st April. A live

male was kept in the cage with the female as long as the latter was alive. On the 21st April she was not so active and seemed to be getting old; she had laid 828 eggs and might possibly have laid some more, but she was injured slightly and could not retain her position on the plant. She died on this date. All the eggs were fertile and hatched. The oviposition record is as follows:—

FEMALE E.

PERIOD.		On stem.	On stem at axils or leaf-stalks or by side of stipules or buds.	In groove of rachis of leaf.	At axils of leaflets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
From	To							
31 Mar.	10 A.M. 7 April.	4	35	46	14	..	33	132
10 A.M. 7 April.	10 A.M. 14 ,,	15	122	101	50	3	124	415
10 A.M. 14 ,,	10 A.M. 16 ,,	9	22	43	1	..	16	91
10 A.M. 16 ,,	9 A.M. 21 ,,	9	16	56	7	..	102	190
								828

Female W emerged on February 17th and was given a male of the same date. On the next day the male was not to be found. On the 22nd February a fresh male was supplied. On the 1st March copulation was noticed at 3-30 P.M. and no eggs had been laid till this date. On the 11th March the male was isolated and it lived until April 1st. The female died on March 27th. The eggs laid between 25th and 27th March did not hatch and were apparently unfertile. The oviposition record is as follows:—

FEMALE W.

PERIOD,		On stem.	On stem at axils of leaf-stalks or by the side of stipules and lateral buds.	In groove of rachis of leaf.	At axils of leaflets.	On leaflets, upper surface.	On leaflets, under surface.	TOTAL.
From.	To.							
1 Mar. when coupled	3 P.M. 11 Mar.	17	44	27	35	2	19	144
3 P.M. 11 Mar.	8 A.M. 15 ,,	..	34	18	22	3	10	87
8 A.M. 15 ,,	8 A.M. 18 ,,	..	26	10	9	..	1	46
8 A.M. 18 ,,	9 A.M. 25 ,,	3	12	10	3	..	..	28
9 A.M. 25 ,,	27 ,,	6	2	..	1	..	..	9
								314

In the fields it has often been noticed that one plant may be literally covered with eggs while the plants surrounding it may have hardly any eggs on them. It is curious that the female or females will remain depositing hundreds of eggs on the same plant while only a short jump is necessary to reach other plants. The following record shows the number of eggs found on two such plants :—

No.	On stem including those at axils of leaf-stalks.	In groove of rachis of leaf.	At axils leaffets.	On upper surfaces of leaflets.	On lower surfaces of leaflets.	Total.
1	93	137	58	192	199	679
2	70	168	49	102	201	590

In the Insectary, too, the same habit has been observed. In one case a female had access, between the 27th February and the 1st March, to two plants growing in the same pot ; she laid 67 eggs on one plant while there was not a single egg deposited on the other. In two other similar cases the females confined with the plants for 24 hours deposited all the eggs on one plant and neglected the second plant altogether. This emphasises the sluggish nature of the adult insect which probably does not leave a plant unless compelled to do so. The period from the laying of the egg to hatching varies, according to season, from five to twenty days, the latter extended period being during January and February. From March to September the period varies from five to twelve days and it is during this period that the insect is most active.

Hatching of the egg.—The egg-shell bursts at the narrower end and the larva which is of a pale yellow colour wriggles its way out. When it emerges from the egg its legs are closely applied to the body and it is held upright in the air by the hinder part being still retained inside the egg-shell. After a while it moves its limbs and bending forward crawls out of the egg-shell on to the leaf of the plant. The egg-shell then closes up again and retains its normal shape, the fissure through which the larva emerged being unobservable even under a low power lens, so that it is difficult to distinguish between hatched and unhatched eggs.

The Larva or Nymph.—The freshly emerged larva (Plate XV, fig. 4) is at first of a uniform pale yellow colour, the eyes only being red. The colour darkens gradually until in the course of a day it is of a general brownish black, the appendages being darker than the body. The divisions of the body are marked by light yellow coloured lines and there is a light coloured median line from the head to the abdomen. The nymph passes through five moults before attaining the winged adult stage.

The time taken for each individual stage in the development of the nymph has only been observed at one period, during March and April 1912, and the results are given in the following table :—

No.	Date of hatching of egg.	Date of 1st moult.	Date of 2nd moult.	Date of 3rd moult.	Date of 4th moult.	Date of 5th moult.
1	16th March 1912	23rd March	25th March	28th March	2nd April	8th April
2	31st ,, ,,	4th April	6th April	8th April	10th ,,	14th ,,
3	31st ,, ,,	4th ,,	7th ,,	10th ,,	12th ,,	15th ,,
4	31st ,, ,,	4th ,,	6th ,,	8th ,,	10th ,,	15th ,,
5	31st ,, ,,	4th ,,	6th ,,	8th ,,	10th ,,	14th ,,

The larva in the first stage is very small, the measurements of a larva three days old being :—

Length from head to tip of abdomen	·3 m.m.
Breadth	·15 ,,
Length of antenna	·07 ,,

Very careful examination is necessary to observe it on the plant. The young larvæ usually crawl up the plant until they reach the young leaves at the growing point, and crawling in among the leaves insert their probosces and commence to suck.

After the first moult signs of the presence of wing pads are observable (Plate XV, fig. 5) and the insect has increased in size, the dimensions of a nymph in this stage being:—

From head to tip of abdomen	·5 m.m.
Breadth across the eyes	·25 ,,
,, ,, prothorax	·28 ,,
,, ,, middle of abdomen	·22 ,,
Length of antenna	·09 ,,
Length of wing pads (anterior)	·08 ,,
,, ,, ,, (posterior)	·05 ,,

A more marked differentiation of the parts of the body is seen, and the colour scheme has changed somewhat, the head and thorax

being of a greyish tinge, and the abdomen pale yellow. The appendages still remain of a dark brownish black, and the eyes red.

In the third stage (Plate XV, fig. 6) little difference is noticeable except increase in size and lengthening of the wing pads.

Length from head to tip of abdomen	·63 m.m.
Breadth across the eyes	·25 ,,
,, ,, prothorax	·26 ,,
,, ,, middle of abdomen	·3 ,,
Length of antenna	·16 ,,
,, ,, wing pads (anterior)	·1 ,,
,, ,, ,, ,, (posterior)	·08 ,,

In the fourth stage (Plate XV, fig. 7) the wing pads are very distinctly enlarged and the colouration of the nymph is generally of a lighter yellow shade, the appendages alone being darker in colour. The abdomen is long in proportion to the rest of the body.

Length from the head to the tip of abdomen ..	1·0 m.m.
Breadth across the eyes	·4 ,,
,, ,, thorax	·4 ,,
,, ,, abdomen	·44 ,,
Length of wing pads (anterior)	·22 ,,
,, ,, ,, (posterior)	·12 ,,
,, ,, antenna	·3 ,,

In the fifth and last nymphal stage (Plate XV, fig. 8) very marked differences are noticeable, the parts of the body and appendages being much more clearly differentiated. The general colour scheme has now become of a dark brownish black, the legs and wing pads and lobes being of a dusky yellow colour with darker shades round the edges. The distal portion of the antenna is black and the remaining part yellow. The entire surface of the body is speckled with grey or whitish markings. The antennæ now show clearly eight distinct joints and the wing lobes have become much longer, the posterior ones being almost entirely covered by the anterior ones.

Length from the head to the tip of the abdomen ..	1·5 m.m.
Breadth across the eyes	·5 ,,
,, ,, the abdomen	·75 ,,
,, between the margins of the anterior wing lobes	1·0 ,,
Length of anterior wing lobes	·5 ,,
Length of the antenna	·5 ,,

The larvæ and nymphs in all stages exude globules of fluid which have a greyish white appearance. The globules are extruded from the anus and consist of liquid excreta covered over with a waxy secretion.* If a globule is placed on a glass slide and pricked with a needle the globule bursts discharging its fluid contents, the waxy covering remaining on the slide.

The nymph moulting for the last time gives rise to the winged adult (Plate XV, fig. 9). The skin of the nymph bursts along the back in the middle line. The insect gradually liberates itself from the skin and moves a little forward along the leaf and remains quietly sitting. The colour is a general pale yellow, except the eyes which are red brown. The wings, which are of course still unexpanded, are about the size of the wing pads in the last nymphal stage. In the insect observed, the wings after a lapse of 45 minutes became fully expanded but no change of colour was noticeable, this not taking place until nearly two hours after emergence.

The young nymphs after hatching from the egg crawl about on the plant and almost invariably come to the top of the stem where they can obtain a good supply of sap. They creep into or between the unfolded tender leaflets and sit hiding there and sucking the sap. If no secure place is to be found among the tender leaflets the nymphs crowd under the stipules. If lateral shoots with tender leaves or newly developing lateral buds are found, many lodge themselves there. The previously mentioned liquid excrement appears in all sorts of shapes, such as pearly globules or long tubules and often quite fantastic forms. The excrement falls on to the leaves and branches, and in moist weather a black mould grows on it giving the plants a blackened, burnt-up appearance. As long as there is food available the nymphs do not desert the plant on which they hatch. It has been observed in several

* In *Psylla mali*, an insect which is very troublesome on apple trees in England, two glands have been found one on either side of the anus and it is possible that the waxy secretion is produced by these glands and covers the excrement as it is extruded. This insect produces the same kind of greyish white globules.—A. J. G.

cases that out of two plants growing in the same pot, one on which no eggs were laid remained free and grew healthily while the other harboured and fed numerous nymphs. The nymphs usually live hidden under the curled leaves inside the crumpled head. When, however, they are full grown and about to become winged they leave their hiding places and come to the stem or open leaves so that the emergence of the adults may not be impeded. For this reason nymphs in the advanced stages frequently sit exposed on the stem, at axils of leaf-stalks or on leaves.

The formation of Colonies.—Colonies of nymphs, consisting sometimes of several hundred individuals, are occasionally formed on the stem below the crumpled head. Nymphs in all stages of growth are found congregated together and are entirely exposed exactly like an aphis colony. Such colonies were not noticed earlier than September. It was then observed that when a large number of nymphs hatched on a head in the leaves of which there was not room for all, or on a head which had practically withered, the nymphs settled on the stem in colonies. Sometimes colonies were formed a great distance below the head of the plant. This gregarious habit renders the nymphs liable to a special danger, *viz.*, the predaceous Syrphus fly, *Pelecocera* sp. described later. In the several plots of indigo kept under observation the Syrphus fly appeared only after the nymphs had begun to form such colonies in exposed places.

The adult.—The adult has recently been described by D. L. Crawford (Indian Museum Records, Vol. VIII, p. 431). His description is as follows :—

" *Psyllopa punctipennis*, n. sp.

Length of body 1·7 m·m.; length of fore-wing 2·3 m.m.; greatest width 1·0 m.m.; width of vertex between eyes ·33. m.m.; with eyes ·53 m.m. General colour light brown; dorsulum and scutum with several dark brown longitudinal stripes, antennæ black at tips of segments III to X; fore-wings with numerous brown or black dots and spots both on veins and membrane.

Head a little narrower than thorax, not much deflexed; vertex longer than half its width, with a slight foveal impression discally; facial cones about two-thirds as long as vertex rather strongly divergent, narrowly rounded at tip; eyes larger; antennæ less than twice as long as width of head, slender.

Thorax not strongly arched; pronotum rather long; pleurites broad. Legs typical. Fore-wings hyaline, rounded at apex, relatively rather small, about two and a third times as long as broad; cubital petiole a little shorter than discoidal subcosta.

Male.—Genital segment rather large; anal valve broad at base, truncate at apex; claspers rather blunt at tip.

Female.—Genital segment thick, about half as long as rest of abdomen, valves subequal, rather thickly pubescent.

Described from four males and four females from Pusa, Bengal, on indigo. This is probably the adult of Buckton's *Psylla isitis* which he described from the nymph only. In order to avoid confusion, however, in case they should not be identical, I have given it another name. The fore-wing of this species bears a close resemblance to *Aphalara multipunctata*, Kuwayama (Japanese)."

The males are easily distinguishable from the females by the marked upturning of the tip of the abdomen (Plate XV, fig. 10) enclosing the accessory sexual organs, the tip of the abdomen of the female being pointed. Coupling has been observed to take place in two ways, either end to end, the axes of the bodies of the two insects being in the same straight line, their heads being turned in opposite directions or, with the axes of their bodies forming the acute angle, the heads of the insects facing in the same direction, the latter being the usual mode. The exact length of the period occupied in copulation was not determined, but couples were observed together for up to one hour and 50 minutes. After copulation the female, as described previously, begins to lay eggs fairly soon.

In the Insectary with a good supply of food the adults, both male and female, lived for up to 39 days. Their usual mode of

locomotion is a sort of flitting from plant to plant. When one disturbs them while they sit on a stem, leaf-stalk or leaflet, they try to evade pursuit by moving on to the opposite side. If the attempt is continued they may walk a little but usually flit away. Although active when provoked they seem to be naturally sluggish. This has been referred to while discussing oviposition. As a rule they do not leave the plant on which they become winged and a number of adults will sometimes be found sitting and mating on plants which still harbour a large number of nymphs. The adults are scarcely ever found sitting exposed to the hot sun. Also when it rains they sit on the under surfaces of leaflets or on leaf-stalks and stem under cover of leaves.

The adults are not attracted by light. On a dark night on the 16th August an acetylene gas light-trap was set up in an affected plot of indigo in which it was ascertained by examination the previous evening and also the next morning that there were numerous adults both male and female. To the trap were attracted several hundreds of bugs, beetles and moths but only five " Psylla " adults, one female and four males.

The effect on the plant.

The damage to the indigo plants is very marked (Plate XVI, figs. 1 & 2). The leaves around the growing point of the attacked plants become curled and twisted up into a knot at the top of the stem, the twisting and curling becoming more and more pronounced as the attack proceeds until finally in the case of Java indigo, the head of the plant forms a hard knot of blackened curled leaves involving the death of the growing point. The effect on the Sumatrana plants too is much the same, the same kind of curling being produced, but on account of the long internodes there is not the same compact knot. The plant usually then tries to compensate for this by throwing out fresh branches from the axillary buds and giving the plant a bushy appearance. These fresh branches in their turn may become attacked by the insect

Fig. 1. An affected plant showing the tightly curled knot of leaves around the growing point.

Fig. 2. Unaffected and affected plants of the same age.

and soon present the appearance of the original plant and if the attack be continued, especially if the plant is young, the plant will be killed outright.

The different species of *Psyllidæ* affect their host plants in different ways. Some merely weaken the plant by sucking its juices but do not cause any malformation. Others, in addition to, or as a result of, sucking their food from the plant, cause gall-like growths to develop, in which they pass their life-history. "Psylla" seems to be intermediate between these two forms, for although no gall is formed the leaves become distorted in shape and growth. It is not known exactly how this alteration in the form of the plant is brought about, but it is probable that the insect in the process of sucking injects some kind of secretion from the salivary or other glands which causes the cells of the plant at the point of puncture to grow unequally, thus producing the malformation. An examination of young leaves just beginning to curl shows that the folded-up leaf begins to curl before the halves open out, and that young nymphs are generally to be found in between the folded halves. This may possibly be explained by the fact that the nymphs secure between the folded halves suck for some time from one-half only, this causing a retarding or acceleration of the growth of that half, while the other half is growing naturally resulting in the curling of the leaf in one direction or the other. In the case of indigo "Psylla" it is only the nymphs which cause the leaves to curl; the adults producing no malformation of the plant as the following experiment shows :—

Four freshly emerged adults were placed upon a healthy plant of Java indigo on 22nd February 1912, and remained on the plant until 20th of March when the plant becoming attacked by red spiders (*Tetranychus*), the insects were removed to a fresh one, on which they lived until between the 26th and the 29th March when they died. On neither plants was there any curling noticeable. The effect of the nymphs is very different. On the 17th February 1912, two plants in a pot were infested with

three nymphs each and on 19th and 20th, respectively, one nymph from each became adult. Yet on the 23rd the leaves of the plants were distinctly curled. It has already been mentioned that the young nymphs after hatching from the eggs invariably come to the tender unopened leaves and suck from them. It was observed in a long series of plants on which adults were made to lay eggs in the Insectary that the newly hatched young nymphs were able to cause distinct curling of the top leaves within two days and to produce the typical crumpled head within a week. It was also found that a single nymph was sufficient to cause crumpling of the leaves.

If the attack on the plant ceases after a time, and has not been severe enough to kill the growing point, the plant will grow through the twisted head and produce normal leaves again. The malformed leaves do not recover, however, though they may grow and open out to some extent. This is shown in fig. 2, Plate XVII, the history of the plant being as follows. Eggs were laid on the plant on 22nd and 23rd February 1912, and hatched on 5th March. Crumpling of the leaves was noticeable by the 14th and the nymphs became adult by the 25th. The adults were not allowed to lay eggs on the plant and it was kept under ordinary conditions with the result shown in the photograph, where it is seen that the leaves around the growing point are quite normal, whilst those lower down about the position where the growing point was at the time of attack, are crumpled and twisted. The effect has also been observed in the field where the crop has recovered under favourable circumstances from a previous attack. Plates XVIII & XIX are a series of photographs of the same plant to show the progress of the disease. A female was confined on the plant on 16th April and eggs were laid on it up to 21st. Hatching commenced on the 23rd and curling was evident by the 27th. Adults appeared on the 7th May and were allowed to lay eggs on the plant. Adults again appeared on 16th May and by June 6th all the nymphs had become adult and left the plant. At this time the growing point of the plant was practically dead, and several side shoots had been given off and had been

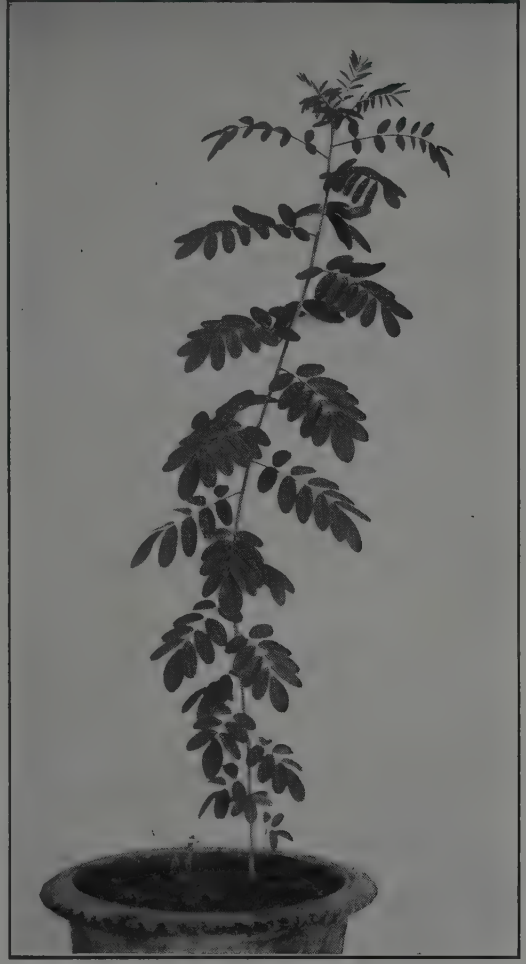


Fig. I. Affected and unaffected plants of the same age. The affected plant has been killed out and the unaffected one grown naturally.

Fig. 2. A Plant recovering from the attack. The curled leaves are seen on the stem in the position where the growing point was when the attack occurred.

Fig. 1. To show the appearance of the plant at the time of inoculation (April 23rd 1912).

Fig. 2. The plant 13 days after inoculation (May 5th 1912).

Fig. 1. The plant 25 days after inoculation (May 17th 1912).

Fig. 2. The appearance of the plant on 29th June 1912, 68 days after inoculation. The growing point is practically dead, side branches have been given off and these in turn are affected.

attacked. Fig. 2, Plate XIX, gives the final appearance of the plant on June 29th.

Food-Plants.

As the growers know to their cost, "Psylla" feeds on both the varieties of indigo at present cultivated in Behar, *viz.*, Sumatrana (*Indigofera sumatrana*) and Java (*Indigofera arrecta*).

Mr. Bergtheil, Director of the Indigo Research Station (now closed) at Sirsiah, was kind enough to supply seeds of the following species of indigo with the remarks noted against each species :—

I. paucifolia, from Forest Office, Dehra Dun, possibly a variety of *Sumatrana*.

I. anil, from Georgetown, British Guiana.

I. oligosperma.

I. tinctoria, sent and so-called by U. S. A. Bureau of Plant Industry ; certainly not rightly named since it yields no indigo.

He also supplied seeds of *Polygonum tinctorium*, a Chinese indigo plant (seeds from plant grown at Sirsiah) and said that all except *I. tinctoria* were indigo-yielding. The seeds were sown in the Insectary compound, but *Polygonum tinctorium* did not grow. "Psylla" was found to feed and breed on *I. paucifolia*, *I. anil* and *I. oligosperma* and curl their leaves in the same way as Sumatrana and Java-Natal. "Psylla" would not feed on the so-called *I. tinctoria*.

Thus it is definitely known that the insect feeds and breeds on :—

I. arrecta, "East African" or "Natal" or "Java" indigo. It is an introduced plant now cultivated in Behar.

I. sumatrana, Bengal indigo. This is also cultivated in Behar. According to Prain, it is occasionally spontaneous in Tamarisk jungles and on river banks. Under this Prain includes *I. tinctoria* mentioned by Roxburgh (*Flora Indica*) who describes it as "native place uncertain, for though now common in a wild state over most parts of India yet is in general not remote from places where it is or has been cultivated," and also part of *I. tinc-*

toria mentioned by Hooker (*Flora of British India*) as "the universally cultivated indigo," but he states further that it is doubtful whether it is truly wild. This too is probably an originally introduced plant.

I. paucifolia. Mr. Bergtheil says this is possibly a variety of *Sumatrana*, but Hooker puts it down as a distinct species giving its habitat as " Plains from Scinde and the Upper Ganges to Ceylon."

I. anil, West Indian indigo. It is said to be sometimes grown.

I. oligosperma is not known to grow in Behar.

Prain mentions six species of *Indigofera* occurring as weeds in Behar. (*I. echinata*, Western Behar; *I. linifolia; I. cordifolia; I. glandulosa*, Western Behar; *I. endecaphylla*, Western Behar; *I. tinctoria*). Of these the species commonly found is *I. linifolia*, a small creeping weed which grows in lawns, pastures and waste lands. No " Psylla " was found on it and all attempts to rear nymphs and adults on it failed. The insects therefore probably cannot breed on it. In the Insectary eggs were laid on this plant by females confined with it, but the nymphs which hatched from these eggs did not feed, and deserted it. None of the remaining five species was tried as they were not available. It is, therefore, not known whether " Psylla " will feed on them. According to Prain, another species, occurring wild in Behar, is *I. articulata*, Surat indigo, which too is an introduced plant and used to be cultivated formerly until displaced by Sumatrana. It is not known whether " Psylla " feeds on this species. He also says that sometimes Guatimala indigo, *I. guatimalensis*, is cultivated. It is not known whether " Psylla " feeds on this species either. Stray plants of both the species of indigo cultivated at present, *viz.*, Java and Sumatrana, are found all over Behar. It is certain that such volunteer plants occur of those species of indigo which had once been cultivated but have now been displaced or which are cultivated only occasionally.

The plants on which " Psylla " feeds ordinarily in Behar, that is the varieties of indigo which are cultivated, are introduced plants,

but it has always been considered that the insect itself is indigenous. It is probable therefore that the insect has other food-plants which occur naturally in Behar and upon which it can live. Attempts were made to discover these plants but without success.

The discovery of the wild food-plants will not probably be a material help in checking "Psylla" under the present conditions as the volunteer food-plants are there and also indigo is in the fields from year's end to year's end. The insect, therefore, is in no want of food throughout the year.

The plants, which have been definitely proved to support "Psylla" and enable it to multiply, are indigo-yielding. An attempt was made to find out whether the insect would feed and breed on plants other than *Indigoferas*, but which contained the substance indican. The following two species were tried but the attempts were unsuccessful:—

Tephrosia purpurea, a perennial herb, common in waste places and by way-sides. This is known in the vernacular as "ban-nil," *i.e.*, "wild indigo."

Tephrosia sp., a variety growing at Sirsiah from whence seeds were obtained.

When Sumatrana was the only indigo grown it was in the land from March to October. Therefore the insects had to depend on other food-plants from November to March. It is uncertain whether it then resorted to its presumed wild food-plants and bred on them, or whether the winged adults lived on other plants and waited through the winter to lay eggs on indigo when it would be again grown in March. If there are wild food-plants present, the former would be the course adopted and there would be no necessity for the adults to wait, especially when, as it has been definitely observed, the cold of winter in Behar does not inhibit breeding. A long series of plants was tried to test if adults would feed and live on plants other than *Indigoferas*. The plants were grown in pots and adults, both males and females together were confined with them as much under natural conditions as possible. The

" Psylla " adults died after two to four days, while under the same condition they live for more than forty days on indigo. Also no eggs were observed to be laid. The plants tried were the following :—

Wheat; Barley; Maize; Pea; Linseed; Cotton; Castor; Tobacco; Sweet potato; Brinjal; Chillie; *Physalis minima; Heliotropium indicum;* Cauliflower; Radish; Aniseed; Jute; a Weed (*Corchorus* sp.); *Akh* (*Calotropis gigantea*); Turmeric; Artichoke; Guma (*Leucus* sp.); *Justicia* sp.; Elephant's Foot; Prahlad (*Ocimum canum*); *Chhatwan* (*Alstonia collaris*); Mango; Papaya; Arum; *Phyllanthus niruri;* Lily; *Dodonea viscosa; Commelyna bengalensis; Mutha* (*Cyperus rotundus*); *Kodo* (*Paspalum scrobiculatum*); *Sama* (*Panicum frumentaceum*); *Marua* (*Eleusine Coracana*); *Juar* (*Andropogon Sorghum*); *Dub* (*Cynodon dactylon*); *Mung* (*Phaseolus Mungo*); *Urid* (*Phaseolus radiatus*); *Arhar* (*Cajanus indicus*); *Chakour* (*Cassia occidentalis, C. sophera & C. tora*); *Amaltas* (*Cassia Fistula*); *Sissoo* (*Dalbergia Sissoo*); *Lajwavati* (*Mimosa pudica*); *Kouni* (*Setaria italica*); *Kanghani* (*Abutilon indicum*); *Simul* (*Bombax malabaricum*); *Chota Dudhi* (*Euphorbia thymifolia*); *Dudhi* (*Euphorbia pilulifera*); *Ghurmi* (*Cephalandra indica*); *Gular* (*Ficus glomerata*); *Pakur* (*Ficus infectoria*); *Pipal* (*Ficus religiosa*); *Rai* (*Brassica juncea*); *Sarson* (*Brassica campestris*); *Bariar* (*Sida* sp.); *Suthni* (*Dioscorea fasciculata*).

This list includes, amongst other plants, almost all the weeds which commonly grow in or near indigo fields.

Effect of Manuring on Affected Plants.

In order to determine if plants well-treated with manure could resist the curling of the top caused by the feeding of " Psylla " nymphs, a few series of experiments were carried out with superphosphate and oil-cake. The plants were grown in pots.

There was no difference in the effect of the attack by the insect on manured and unmanured plants. Both were curled to the same extent and in the same way. As soon as curling of the top occurs and checks the growth of a manured or any vigorously growing plant, it begins to give out lateral branches and become bushy. Thus if there had been only one attack of "Psylla", that is, if the insect had fed on the plants for only one generation and then left them, probably the attack would have been a blessing in disguise; as it would have made the plants grow bushy and produce more leaves. But actually all fresh shoots are attacked as soon as they appear and the growth of the branches as well is stopped.

How Infection Takes Place.

Infection of new areas is probably effected by females flying over to them and in these cases the insects are probably helped by the wind. In this way infection is spread from one place to another as the following instance illustrates. A plot of Java indigo was sown on the Farm at Pusa in October 1911, the nearest indigo cultivation being at least two miles away, and no indigo had been grown on the Farm for years. On 28th February 1912, a number of plants showed signs of attack and nymphs were found on them. In some cases, however, the insect does not seem to spread very rapidly, for a small plot of Java indigo sown in the Insectary compound on 29th November 1911, remained free from attack until the end of June, although the formerly mentioned plot was attacked in February, though in this case the plants were grown in among Kusum (*Carthamus tinctorius*) plants, these latter plants being removed on the 21st April 1912. The facilities for infection were very great, however, for breeding experiments were being carried out in the Insectary from February onwards and infected plants in pots were often standing in the verandah at a distance of not more than ten yards from the plot, and it would have been a very simple matter for winged insects to fly from these plants into the plot.

It has also been observed that infection is either prevented or retarded when the adults meet with some sort of obstruction. Thus Java-Natal indigo was grown in a big wire-gauze cage attached to the Insectary. The wire-gauze had about 10-12 meshes to the linear inch which would allow easy passage to "Psylla" adults. The indigo was growing from November 1911 to January 1913, but no insects appeared in this cage although it was breeding profusely at a distance of about 5 yards. It was observed on other occasions that when indigo was sown together with other crops such as wheat, linseed, mustard, the young plants showed little or no sign of attack when the covering crop was removed, whilst other indigo grown in the ordinary way and in its immediate vicinity was badly affected.

The spread of infection in a plot of indigo seems almost always to be effected by the adults, though it is possible that the nymphs may leave one plant and crawl over the ground to a fresh one. To test the capacities of the nymphs for walking over the ground, the following tests were made. Twenty-five nymphs of different stages were placed at 10 A.M. on earth which had been smoothed in a pot in which a plant of indigo was growing. Five more shoots of indigo were then stuck into the earth at intervals of about two inches. The nymphs immediately crawled away in different directions at the rate of about an inch a minute. The first one crawled on to a shoot within a minute and-a-half, and at the end of ten minutes seven nymphs were on the shoots. At 4 P.M. it was found that sixteen nymphs had crawled on to the plants, three were found dead on the rim of the pot, and the remainder had disappeared probably having crawled right away from the pot.

A large number of nymphs were placed on the ground in a field which had been ploughed and afterwards smoothed down by rain. They were found to be able to walk over a distance of about five to six feet or more. They did not make much progress because they wandered about, got upon any plant or stick they came across and also fell an easy prey to ants and other predaceous enemies. When they could not get to the proper food-plants,

they died within a day for want of nourishment. It has also been found by placing the nymphs in ploughed up lands with a loose surface that they travelled extremely slowly, and in fact could hardly make any progress at all. The nymphs and adults also do not seem to be able to withstand the absence of food for long. Seven crumpled heads with many nymphs in all stages, and five adults were placed in a glass dish with a wire gauze cover at 7 A.M. At 7 A.M. the next morning the shoots were found to have withered a great deal and that two of the adults were dead and also that many of the nymphs had left the shoots and were walking about in the dish. By 4-45 P.M. the shoots had withered considerably and only one adult was living, the nymphs had all left the shoots and many of them were dead. At 10 A.M. on the third day it was found that all the nymphs and adults were dead. This fact is of interest in connection with the severe attack from which the *khoontie* crop usually suffers, for it would seem that the cutting of the crop at that time should effectually check the insect and when the plants are cut, little beyond the hard stems of the plants would remain in the field and the nymphs at any rate would be killed off.

At the time of harvesting, the operation of cutting the plants, placing them on the ground in bundles and then loading these bundles on to carts, is not at all sufficient to jerk the nymphs from the plants. Some do fall off on account of the disturbance caused, but their number is very small as has been determined by actual observation. These fallen nymphs mostly crawl on to the cut stumps and live there until new buds grow. The insects develop undisturbed on the occasional plants left standing here and there and the adults soon infect the *khoontie* plants around. Sometimes a cut plant is left lying on the ground and as it withers the nymphs crawl on the stumps which afford them nourishment for about three days or so by which time new buds sprout. Apart from these nymphs the number of which is small, the adults are the principal source of infection of the *khoontie* crop. In a newly harvested field adults

are found plentifully. They congregate mostly on the uncut plants left standing here and there. Eggs are laid on such plants and also on the stumps. The cracked epidermis of the latter affords convenient places for oviposition and when the nymphs hatch after 5 or 6 days they find the newly sprouting buds to feed upon. Also all the plants in one district are not cut simultaneously so that the winged adults can fly from locality to locality and renew the attack.

The question also arises whether the nymphs or adults are carried away to any extent with the plant when it is taken to the vats. On observation it was found that the adults are not dislodged if the plants are merely shaken, as by the wind, but that if the plants are struck with a stick the sudden jerk causes them to leave the plant. The nymphs, however, are more difficult to dislodge and neither shaking, striking the plant with a stick, nor even on the ground has any effect at first, though such disturbance causes the nymphs to leave their lurking places and wander about when the effect of a sharp jerk is sufficient to dislodge them.

The infection of the *khoontie* or young crop quickly takes place if it be by the side of old infected indigo. By the side of an experimental plot of Java-Natal indigo with plants about 3 to 4 feet high a plot was sown with *Indigofera paucifolia*. " Psylla " was breeding unchecked in the Java-Natal plants. The adults bred on this old indigo showed a decided partiality towards the young *paucifolia* plants, to which they were attracted in large numbers, the young plants affording a more plentiful supply of sap.

The Effect of Dew.

In Behar the dews are very heavy from September onwards, and in the early morning the indigo plants in the field are completely covered. The insects are, however, protected by the numerous hairs on their bodies and the moisture has no effect upon them although they may be completely covered. A series of nymphs were completely covered over with dew, but the only result was that they remained quiet until the dew evaporated and then moved away.

Dew however seems to hinder egg laying and thus probably contributes towards the lessening of the number of insects distinctly noticeable in September and October. Covered with dew the adults were found to be quite lethargic and would hardly move even when touched. They became active again when the dew evaporated. Egg laying takes place mostly in the evening, at night and in early morning. But all this time the adults remain covered with dew and therefore egg laying is hardly possible.

"Psylla" and Ants.

The following six kinds of ants have been observed to attend "Psylla":—

Camponotus compressus, the common big black ant, has been observed to attend both nymphs and adults. The adult insect does not jump away even when approached and caressed by this ant. This fact is taken advantage of by the black spider which mimicks this ant and which can thus approach adults unsuspected. This spider (see *enemies*) catches and eats adults.

Tapinoma melanocephalum, a black headed small brown ant, which when pressed between fingers gives out an aromatic smell. It attends upon the nymphs.

Monomorium indicum, the common small brown house ant, has been observed to attend the nymphs. There is a small spider which mimicks this ant. It could not be ascertained whether it preys upon the insect nor could it be fed with "Psylla" in confinement.

Œcophyla smaragdina, the common red tree ant, attends the nymphs.

Camponotus sericeus has been observed attending the nymphs in company with *Œcophyla smaragdina*.

Monomorium gracillimum, a common small brown ant with a dark abdomen has been observed attending the nymphs.

The ants are attracted by the liquid excrement which they lick up by applying their mouth parts to the liquid drop as it

collects at the hinder end of the insect. The ants stroke the insects with the buccal appendages and antennæ. The caresses are evidently not disliked as the "Psylla" nymphs and adults do not appear to be in the least disturbed by the overtures of even such big ants as *Camponotus compressus*.

Enemies.

The Indigo "Psylla" is attacked by a parasite in the nymphal stage and by many predators in both nymphal and adult stages. Nothing has been found to attack the eggs. The influence of these enemies upon the insects has been discussed by Lefroy in the *Agricultural Journal of India*, Vol. VIII, Part 1, page 14.

The Parasite (Plate XX, fig. 4).—The parasite is a minute *Chalcid* which deposits eggs in the bodies of the nymphs. As only one parasite hatches out of one nymph it seems that only one egg is deposited in the same nymph. Just before the nymph dies, it becomes fixed to a leaf or stem and is then merely a shell or case in which the parasitic grub pupates. The parasitised nymphs are not distinguishable until they reach this stage. At this time they become bloated and turn brown in colour and are therefore easily observed (Pl. XX, fig. 5*b*). The actual period from the time of pupation till the emergence of the parasite could not be observed, but it was noticed that about five to six days from the time that the nymph is clearly distinguishable as parasitised, the adult parasite comes out by gnawing a hole in the abdominal region (Pl. XX, fig. 5*c*). The parasite takes about a week and a half to attain to the adult stage from the egg.

The parasite appears to attack only the nymphs of the fifth or penultimate stage. No younger nymph has been observed to be parasitised. Several parasites were observed to have access to large numbers of nymphs of all stages, but only some nymphs in the later stages proved to be parasitised. Compared with some of the predators the parasite occupies a minor place as a check upon the pest. Thus only nine nymphs in a colony of forty, one

collects at the hinder end of the insect. The ants stroke the insects with the buccal appendages and antennæ. The caresses are evidently not disliked as the "Psylla" nymphs and adults do not appear to be in the least disturbed by the overtures of even such big ants as *Camponotus compressus*.

Enemies.

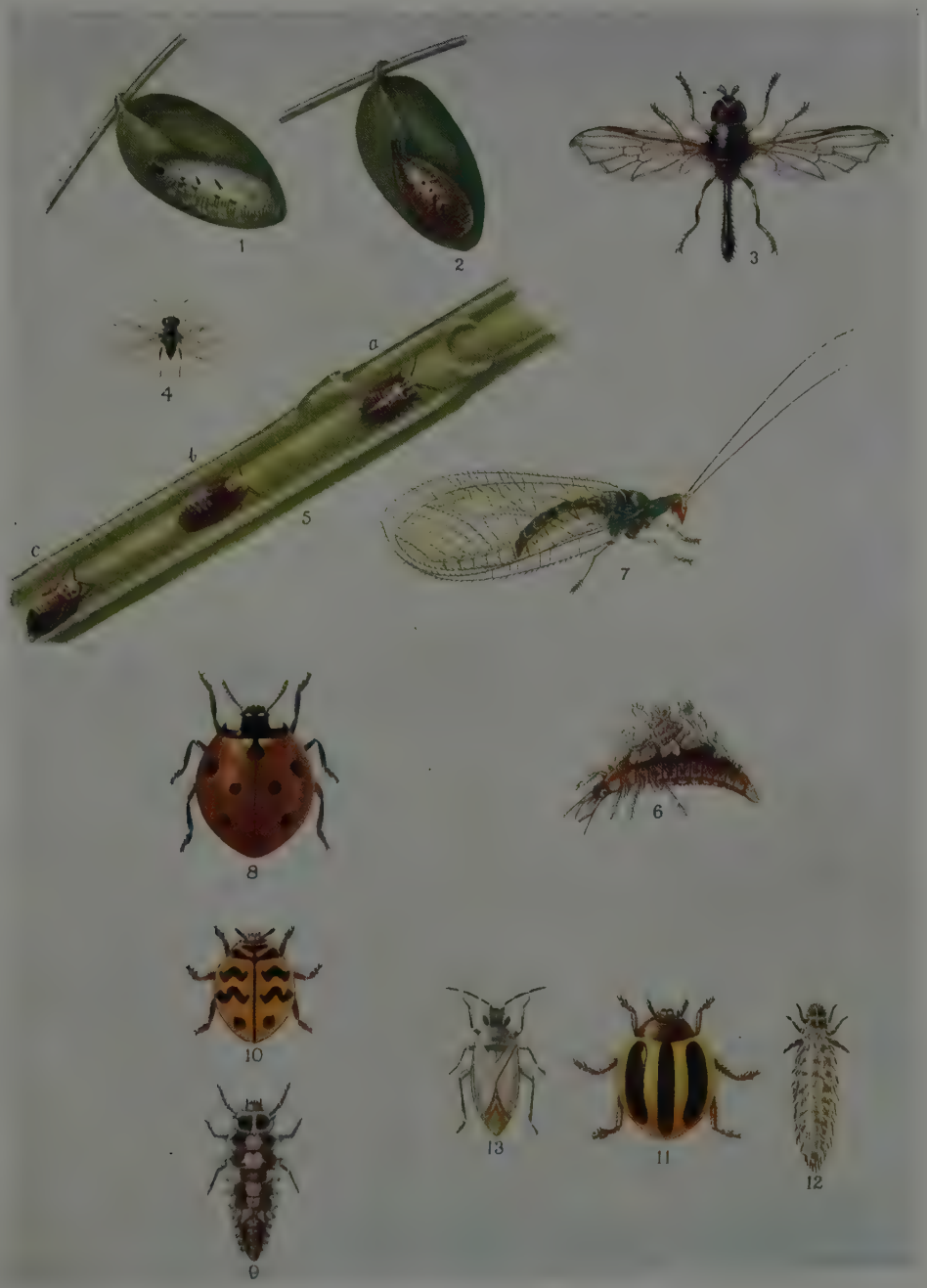
The Indigo "Psylla" is attacked by a parasite in the nymphal stage and by many predators in both nymphal and adult stages. Nothing has been found to attack the eggs. The influence of these enemies upon the insects has been discussed by [illegible] in the *Agricultural Journal of India*, Vol. VIII, Part 1 [illegible].

EXPLANATION OF PLATE XX.

1. Larva of Syrphus fly (*Pelecocera* sp.) X 3.
2. Pupa [illegible] X 3.
3. Imago [illegible] X 3.
4. Chalcid parasite [illegible] X 7. fig. 4).—The parasite is a minute
5. Nymphs of "Psylla" on a shoot.
   (*a*) A full-grown nymph. X 7.
   (*b*) A parasitised nymph. X 7.
   (*c*) A parasitised nymph from which the parasite has emerged showing the hole caused by its exit. X 7.
6. Larva of Chrysopa. X 3.
7. Imago of X 3.
8. Adult of *Coccinella septempunctata* X 3.
9. Larva of *Chilomenes sexmaculata* X 3.
10. Adult of X 3.
11. Larva of *Brumus suturalis* X 7.
12. Adult of X 7.
13. [illegible] of *Campylomma livida* X 7.

[illegible] distinguishable until they reach this stage. At this time they [illegible] brown in colour and are therefore easily observed (Pl. XX. fig. 5b). The actual period from the time [illegible] parasite could not be observed, [illegible] that about five [illegible] six days from the time that the [illegible] distinguishable as parasitised, the adult parasite [illegible] by gnawing a hole in the abdominal region (Pl. XX. fig. 5c). The parasite takes about a week and a half to attain the adult stage from the egg.

The parasite appears to attack only the nymphs of the fifth or penultimate stage. No younger nymph has been observed to be parasitised. Several parasites were observed to have access to large numbers of nymphs of all stages, but only some nymphs in the later stages proved to be parasitised. Compared with some of the predators the parasite occupies a minor place as a check upon the pest. [illegible] only nine nymphs in a colony of forty, one



ENEMIES OF INDIGO PSYLLA.

in a colony of a hundred, and nineteen in a colony of fifty were killed by the parasite, while one maggot of the Syrphus fly (*Pelecocera* sp.) is alone capable of destroying several such colonies in a day.

The Predators.—These destroy nymphs and adults, either eating them or sucking them dry. Among them are included three Ladybird Beetles, a Mantid, a Chrysopa, a Syrphid fly, a Capsid bug, and several spiders. These are known definitely to prey upon the insect and possibly other insects and animals also do so.

The Ladybird Beetles are the seven-spotted *Coccinella septempunctata* (Pl. XX, fig. 8), the six-spotted *Chilomenes sexmaculata* (Pl. XX, fig. 10) and the striped Ladybird Beetle *Brumus suturalis* (Pl. XX, fig. 11). These beetles as well as their larvæ feed principally upon the nymphs and also upon the adults when they can be caught. Figure 9 in Plate XX shows the larva of the six-spotted Ladybird Beetle. The larva of the seven-spotted Ladybird Beetle is similar in appearance but having yellow spots in addition. Figure 12 in Plate XX shows the larva of *Brumus suturalis*. The white tufts on its back give it a characteristic appearance.

The Mantid which has been observed to eat "Psylla" nymphs and adults but mostly adults, is the green one, *Hierodula westwoodi*, commonly found among green vegetation.

The Chrysopa, whose larva has been observed (Pl. XX, figs. 6 & 7) to feed mostly upon the nymphs is the common green one, *Chrysopa alcestis*. The larva has the habit of piling upon its back the empty skins of the nymphs it destroys.

The Syrphid fly (Pl. XX, figs. 1—3) is the most important of all the enemies as it is capable of destroying a large number of the nymphs in a short time. The maggot feeds upon the nymphs only, and during the latter part of its larval history will destroy about 300 to 400 of them in a day. A maggot is shown resting on a leaf in fig. 1, Pl. XX. When it walks or feeds the anterior part of the body is extended and is then tapering in appearance. At the dorsal area of the hind end there is a pair of brown tubes

joined together and giving the appearance of a tail. These are the spiracular openings. The maggot strikes its head apparently blindly in all directions and on the backs of the nymphs, but some nymphs are passed over. It does not pierce the prey from the back, but moves its head round to the ventral surface and then pierces the thorax. The contents of the body are then eaten and the empty skin discarded. The maggot is a voracious eater and feeds almost continuously with but short periods of rest for moulting. It takes about one to four minutes to finish eating a nymph, the time varying according to the size of the prey. Dead parasitised nymphs are always passed over and never destroyed. Membracid nymphs sitting near or in the midst of "Psylla" colonies were not observed to be eaten, but the maggot preys readily on other younger and smaller *Syrphus* maggots which it may come across. When it is full grown it fixes itself by the tail end on either of the surfaces of a leaf or on the stem and pupates there. The anterior end of the pupating maggot is much contracted so that this end of the pupa is rounded (Pl. XX, fig. 2). The fly (Pl. XX, fig. 3) emerges after about seven days. Ordinarily when found in indigo fields it may be mistaken for a small *Eumenes* wasp. It does not exhibit the hovering flight characteristic of *Syrphus ægyptius* and flies more like a *Eumenes* wasp with the abdomen raised than like a fly. Eggs are deposited singly near "Psylla" colonies. Each egg is cylindrical and slightly bent on one side; one end is slightly thicker and rounded, the other end being tapering and blunt. It measures ·7 m.m. long, ·35 m.m. broad and is white in colour. The surface is reticulated, there being fine zig-zag lines noticeable on it under a high power lens. The thicker end is gummed to the substratum and the egg lies on its concave side.

The maggot is found to be parasitised by a small *Chalcid*. It pupates with the parasitic grubs inside its body, the adult parasite emerging by a hole gnawed in the pupa case.

The Capsid bug is *Campylomma livida*, Reut. (Pl. XX, fig. 13) which is a small green bug found in all its stages on the crumpled indigo tops or rather hidden among the crumpled

leaves. The nymphs move about very quickly and the adults too, are very active and fly away when disturbed. The bug is found thrusting its beak into and among the crumpled leaves to get at the young nymphs which always live hidden in such positions and are thus safe from other enemies.

The spiders prey upon the "Psylla" adults only. Three species were definitely observed to spin webs across the affected indigo plants. The adults were caught in the usual way on the webs. Probably all spiders which live in the indigo fields will be found to prey upon "Psylla," as a matter of course.

Another black spider has been found catching and eating adults. It does not spin a web and mimicks the black ant, *Camponotus compressus* which attends the "Psylla", both nymphs and adults. It moves about briskly on the plants in search of the prey. Occasionally it rests for some time on a leaflet and again begins to reconnoitre quickly.

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